*Type of the Paper (Article.)*

# Cyclone Evacuation Route Identification Using GIS for Coastal Communities in Mirzaganj Union, Patuakhali, Bangladesh

**Maruf Billah [1]*, Sraboni Sarker [2] and Mehedi Ahmed Ansary [2,]**

[1]  Graduate student, Institute of Water and Flood Management, BUET, Dhaka, Bangladesh; marufbillah413@gmail.com

[2]  Undergraduate student, Faculty of Disaster Management, PSTU, Patuakhali, Bangladesh; srabonisarker8829@gmail.com

[2]  Professor, Department of Civil Engineering, BUET, Dhaka, Bangladesh; ansary@ce.buet.ac.bd

*  Correspondence: marufbillah413@gmail.com; Tel.: +88-017-614-28534

**Abstract:** Evacuation is the primary and most important preparedness initiative to save people from the devastating effects of a cyclone. For proper evacuation, a route is specifically chosen that will play a role during cyclones. In this study, Geographic information system has been applied for evacuation route planning for Mirzaganj Union, Patuakhali, Bangladesh. The study is based on questionnaire surveys; direct observation and literature review on the existing sheltering system and develops an evacuation route using the shortest distance analysis. This study provides us an idea how we can manage our population to find out suitable nearby shelters and the limitations that we should focused on. The result shows that only 12% of the total population gets shelter opportunity with the existing official shelter capacity by identifying evacuation route with the shortest distance and the shortest time needed. Shortest distance and time have been calculated for each cyclone shelters. If we consider the low vulnerable infrastructures as shelter, 75% of the total population can be accommodated. This study demonstrates the utilization of an ideal evacuation route planning in the coastal parts of Bangladesh.

**Keywords:** Cyclone, Cyclone Shelter, Evacuation, Network Analysis, Bangladesh

## 1. Introduction

 Different natural disasters, such as cyclones, droughts, and floods are increasing globally in recent years [1], [2]. Cyclones are considered as the world's leading natural disasters that even exceed the effects of earthquakes [3]–[6]. Bangladesh is the most vulnerable area to cyclones because of its geographical location at the triangular shaped head of the Bay of Bengal [7], due to its high population density and the absence of effective coastal protection systems. In the pre-monsoon (April–May) or post-monsoon (October–November) seasons, at least one major tropical cyclone hit the Bangladesh coastal region each year [8], [9]. Approximately one-tenth of global tropical cyclones occur in the Bay of Bengal [10]. About one-sixth of the total cyclones developing in the Bay of Bengal make landfall on the coastal parts of Bangladesh [11]. If a cyclone occurs in tropical regions, it is known as a tropical cyclone. Cyclones occurring elsewhere are known as extra-tropical cyclones [12], [13].

Existing literature shows that several devastating cyclones have stuck Bangladesh in 1822, 1876, 1961, 1965, 1970, 1991 and 2007 [4], [14]. Among the 64 districts of Bangladesh, 19 are the located in the coastal areas. The population of this area is near about 36.8 million and more than half of the population (52%) are poor and about 41% is under the age of 15 [15]. In spite of the poverty and being the most vulnerable to different kinds of coastal disasters, with their traditional indigenous knowledge and perceptions, these coastal people are coping with different kinds of disasters and passing their lives with relentless struggle [16]. Two destructive cyclones occurred in 1970 and 1991, with more than 500000 and 140000 causalities, respectively. However, in the last 20 years, Bangladesh has been able to reduce deaths and injuries from the cyclones. For example, the recent major cyclones like Sidr of 2007 and Aila of 2009 caused 3406 and 190 deaths only, about a 100-fold reduction of lives compared to the deadliest 1970 and 1991 cyclones [17]–[20].

As controlling the occurrence of natural disasters is almost impossible, the loss of life and property from these disasters can be minimized or prevented if proper precautions and preventive initiatives are taken timely. For saving human lives the fictitious solutions is to build the habitation above the surge level and construct them strong enough to resist high wind speed and the surges [21]. Nevertheless, the majority of coastal residents are living under poverty level in poorly constructed houses that are vulnerable to cyclone [22]. Existing literatures shows the importance of constructing raised platforms, reinforcement of homestead structures, overall cyclone proof houses in reducing casualties [23]. Besides, focus has been given on infrastructures stability and different infrastructures types to respond to cyclone like temple shaped house and elevated houses [24]. Locations and pattern of settlements are the most important factor to decrease vulnerability of the coastal people. Scattered settlements in the coastal areas are more susceptible to cyclone [25].In the recent past, GIS and RS technology have increased the accessibility in the cyclone occurrence stage in order to develop map and assess the vulnerability of lives and infrastructures of cyclone-prone areas [26], [27]. In developing countries it is badly in need to develop good quality and quantity GIS database for evacuation management. GIS and RS technology can contribute the management process in other hazard prone area like drought, storm surge, flood, land slide, salinity intrusion. So, there is a scope to work with the application of GIS and RS in disaster management especially in the country like Bangladesh.

The next solution is evacuation of the coastal people to the high ground above the surge level [21]. Evacuation is considered as the primary preparedness action against any large-scale disasters like the cyclone. An early warning system also plays a valuable role in the evacuation of vulnerable people during the occurrence of the disasters along with minimizing the loss [28]. The effective early warning system provided by the government in advance of Cyclone Sidr, Aila, Mohasen, Komen, Roanu, Mora in 2007, 2009, 2013, 2015, 2016 and 2017 enabled successful evacuation of coastal communities that resulted in fewer than expected deaths. Besides the early warning systems, different activities like construction of cyclone shelters, embankment, and timely evacuation have contributed to decreasing the death rates in the coastal areas [20], [29].In spite of the improvements in early warning systems, pre-cyclone evacuation remains a challenge [28]. Some factors like illiteracy, lack of awareness, structural vulnerability and communication problems including poor road networks are the obstacles that hamper the evacuation system. Instead of moving to cyclone shelters, people in coastal areas still believe in a wait-and-see approach [30]–[32]. On the other hand,

82  access to road network, distance of cyclone shelters from the homestead, and access to cyclone
83  shelters are the factors that influence the evacuation decision [33].

84      Cyclone shelters play an important role during the evacuation. It has been estimated that around
85  1.5 million people have been evacuated by CPP (Cyclone Preparedness) volunteers to the multi-
86  purpose cyclone shelters (MPCS) when Cyclone Sidr hit the coastal parts of Bangladesh in 2007 [34],
87  [35]. Before the destructive cyclone of 2007, Bangladesh had only 1500 cyclone shelters in the coastal
88  districts as the infrastructural support during cyclone. After Sidr, Bangladesh Government has
89  constructed around 2000 new cyclone shelters for the population of the coastal belt. The World Bank
90  surveyed and further estimated that there is still a need for 5500 new MPCS (Multi-Purpose Cyclone
91  Shelter) facilities for the purpose of a disaster management strategy [34], [36]. GIS-based map has
92  been produced to know about the coverage area of a shelter and need for new shelters [37].

93      Despite of completing these initiatives, the evacuation route to cyclone shelters from any
94  community remains a challenge and is not well defined. People living in the coastal areas are not
95  aware of the appropriate evacuation plan and route during cyclones. They can't take the decision
96  during cyclones in which shelter they should go and which shelter is within their reachable distance.
97  It is common that computing shortest paths over a network is an important task for evacuation. With
98  the development of geographic information systems (GIS) technology, network and transportation
99  analyses within a GIS environment have become a common practice in many application areas.
100 Different factors like easy accessibility of the community people to the shelter with maximum
101 walking distance for an individual is restricted to 2.25 kilometers, covering the entire population of
102 the region by producing safe zones and evacuation zones, suitability of the shelters for other
103 community activities are needed to follow [38], [39]. There exists digitized road map including road
104 class, distance and shortest optimum route [40].Many network flow model including logistics
105 coordination model has been built for identifying optimal lane-based evacuation routing plans in a
106 complex road network by using mixed-integer programming solver [41]–[43]. There exist gaps in the
107 above papers for identifying the shortest distance analysis which is needed during an evacuation
108 process. In the reviewed papers, shortest distance have been analyzed in a map for a vast area without
109 presenting numerical values of the distance from evacuation point to the shelters. Even how many
110 people could be evacuated from each point has not been defined. As Bangladesh is a cyclone prone
111 country, proper evacuation route is a need to reduce the number of affected people. This paper
112 presents an evacuation route planning for Mirjaganj union of Patuakhali, Bangladesh using the
113 shortest distance analysis for each shelter as well as shelter capacity analysis.

114 **2. Materials and Methods**

115     The research is based on both secondary and primary data collected through household
116 questionnaire survey. The total sample size for the household questionnaire survey has been
117 considered 3220 households. In questionnaire survey about different variables have been used to
118 analysis the existing structural condition against cyclone hazard in which they live in. Different
119 variables have been discussed in details in table 2. After collecting the data, ArcGIS10.1 and Microsoft
120 excel have been used to analyze the collected data. ArcGIS10.1 has been used in developing maps,
121 geographic data analysis, editing, data management, and geo-processing activities and also been
122 used in finding the closest shelter facility location, origin-destination (O-D) distance generation and

123  location allocation. A realistic evacuation planning with the shortest route to shelters has been
124  proposed in this study and has been validated using field data.

125  *2.1 Study Area*

126     Figure 1(a) shows the past records of cyclones that hit Bangladesh. Among the Unions of
127  Patuakhali district, Mirzaganj Union is one of the most vulnerable unions to cyclone hazard. Area of
128  Mirzaganj Union is 34 square km, located in between 22°13' and 22°29' north latitudes and in between
129  90°08' and 90°19' east longitudes. Total amount of road is near about 90 kilometers, among these
130  paved roads are 20 km, herring bond roads are 10 km and earthen roads are 70km. There are
131  7secondary schools, 23primary schools, and 16madrasa. Main source of income is agriculture with
132  8527 acres of cultivable land. Due to the geographical location that union has been severely affected
133  by 2007 cyclone Sidr and 2009 Aila. Figure 1(b) shows the location of the union.

134

(a)                                                             (b)

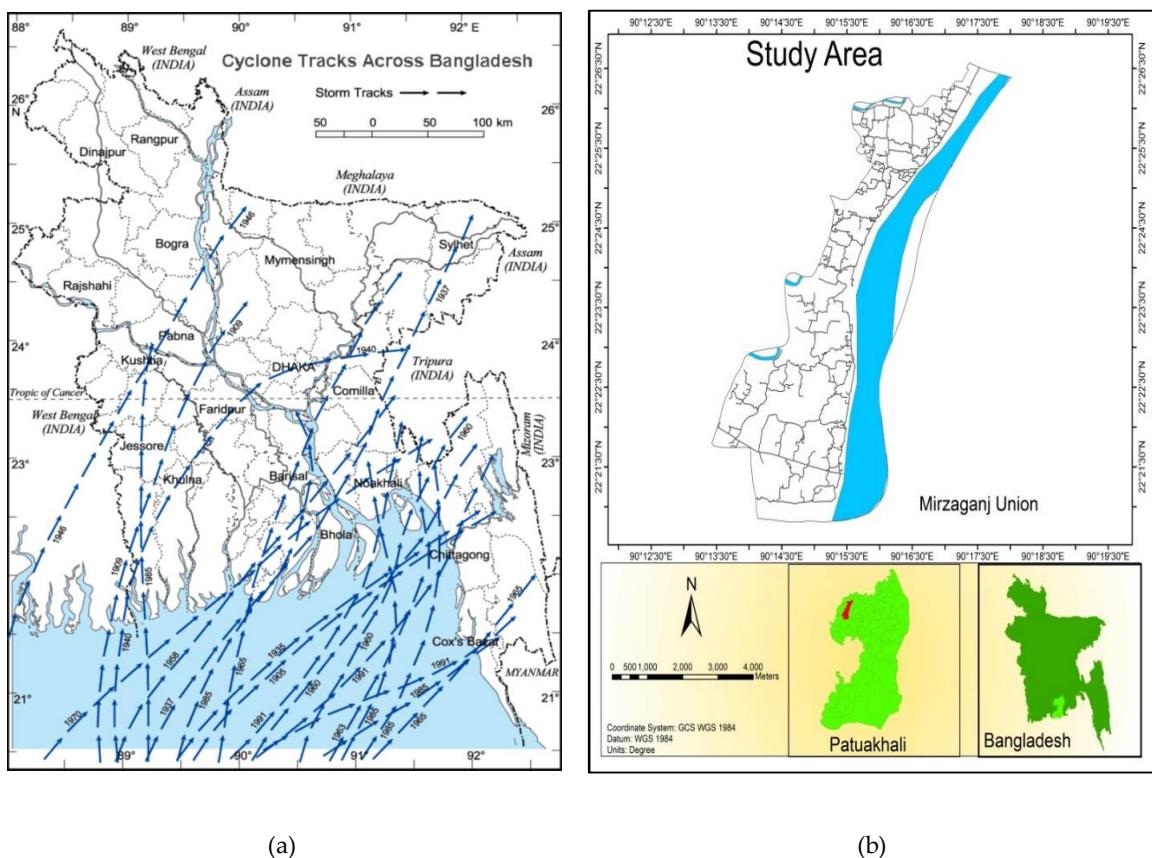



**Figure1:** (a) Cyclone Tracks in Bangladesh and (b) Study Area (Mirzaganj Union)

135  **3. Results and Discussion**

136     Mirzaganj union is bounded by the Payra River on the south and east, the Srimanta River on the
137  west as can be seen in Figure 1(b).According to the Jatiyo Batayon, and there are 11 villages in this
138  union. Total population is 22100. Among them male is 11073 (50.10%), female is 11027 (49.89%). After
139  surveying 3220 households, it has been found that average 7 people live each in household. The
140  literacy rate of the union is 70% including 13033 voters. Most of the people are farmers and small
141  shopkeepers.

142   *3.1 Condition of the Existing Cyclone Shelters and Infrastructures*

143   In Mirzaganj area there are only two usable cyclone shelters (Figure 2). The shelters are designed
144   to withstand a wind speed of 260 km/hour and placed on a higher ground to avoid the effect of the
145   maximum expected surge level. Shelters have been constructed with the required facilities (Table 1).
146   The shelters buildings are primarily used as schools. Shelters are designed in such a way that both
147   human and livestock can take refuge there.

(a)                                                                    (b)

148   **Figure 2:** (a) Cyclone Shelter no 1; (b) Cyclone Shelter no 2.

149   **Table 1:** Details about Existing Cyclone Shelters

| Different Attributes | Cyclone Shelter no 1 | Cyclone Shelter no 2 |
|---|---|---|
| Name | Vazna Monoharkhali Govt. Primary School cum Cyclone Shelter | Vikakhali Govt. Primary School cum Cyclone Shelter |
| Location | 5 minutes walking time from Mirzaganj ferry ghat | 5 minutes walking time from Vikakhali ferry ghat |
| Date completion | January, 2018 | February, 2014 |
| Type of Shelter | LGED type 3 | |
| Source of Fund | GoB and World Bank | |
| Structure | • Three storied building<br>• Open ground-floor structure to avoid flooding from the storm surges<br>• Open first floor with tube-well facilities is kept for cattle with ramp to move on it.<br>• Second floor with room and bathroom facilities for human shelter | |

| | |
|---|---|
| Capacity | 1300 |
| Total Room | In total 6 rooms, 4 large size rooms and 2 extra rooms with attached bathroom for pregnant women and children. |
| Facilities: | •Total 4 bathrooms (2 attached)<br><br>•Two motors for drinking water<br><br>•Four tube-wells<br><br>•4 water tanks capacity with 2000 liters<br><br>•4 water tanks capacity with 7000 liters (especially in cyclone shelter no 1)<br><br>•Solar system is installed<br><br>•Rain water harvesting system (especially in cyclone shelter no 1) |
| Livestock Capacity | 200 |

150   *Source: Field Survey, May 2018.*

151      The official capacity of each cyclone shelter is 1300 people. A large amount of people (about
152   19000) have to stay at their own place due to lack of space in the shelters. That's why a survey has
153   been conducted on the condition of households and their vulnerability to test if they can withstand
154   cyclone or not. The survey has been conducted through a semi-structured questionnaire to measure
155   the vulnerability of the existing households. Table 2 presents the criteria used in the questionnaire to
156   assess the vulnerability of the infrastructures. Scoring has been done depending on the criteria. There
157   are individual houses, schools, mosques and others structures of the assessed infrastructures, some
158   of which are shown in Figure 3.

159

(a)                                    (b)                                    (c)

160                    **Figure3:** (a) Homestead; (b) Mosque and Madrasa and (c) School

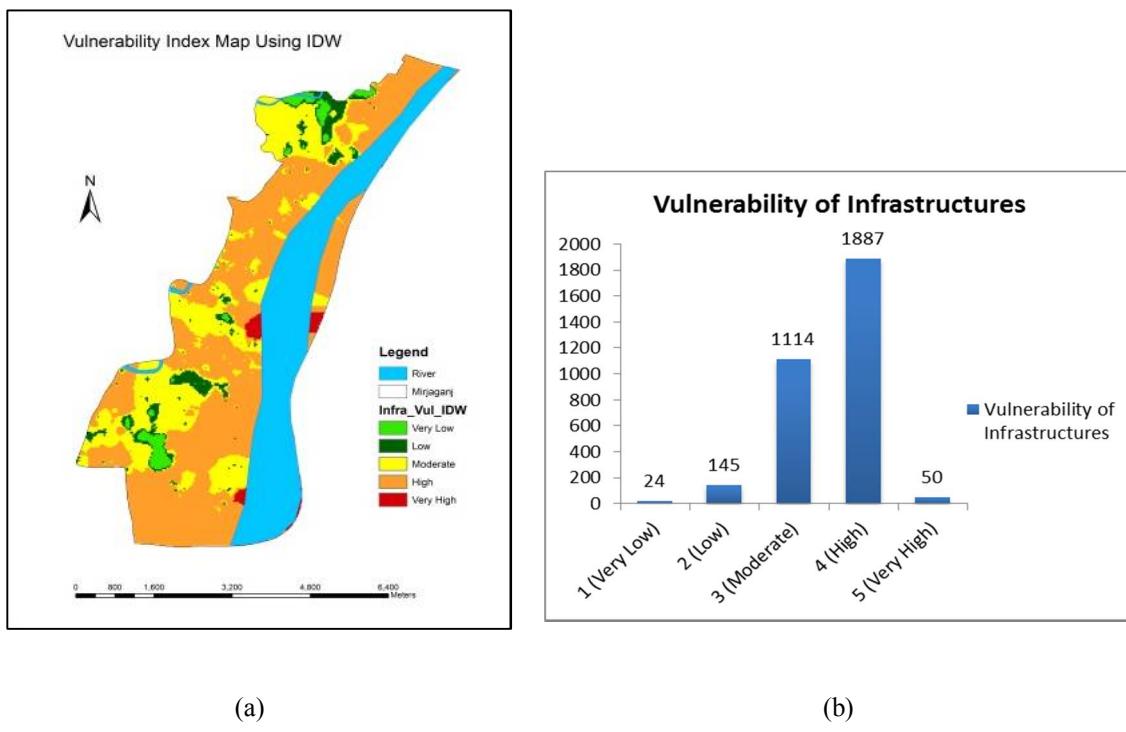
161    **Table 2:** Infrastructure Vulnerability Scoring

| Criteria | Sub-Criteria | Score |
|---|---|---|
| Width of the house is perpendicular to nearest river's length | Yes | 1 |
|  | No | 4 |
| House is in the safe distance from the biggest trees | Yes | 1 |
|  | No | 4 |
| There is sufficient amount of trees around the house | Yes | 1 |
|  | No | 4 |
| Which type of house that is? | Concrete | 1 |
|  | Tin | 5 |
| Size of house(floor area) | Square | 1 |
|  | Rectangular or L shape | 4 |
| Plinth level | 4' | 1 |
|  | Less than 4' | 4 |
| Ridge level | High | 1 |
|  | Low | 4 |
| Wall | Concrete | 1 |
|  | Wood | 3 |
|  | Tin | 5 |
| 'J' hook presence | Yes | 1 |
|  | No | 5 |
| Post of house | Concrete | 1 |

|  |  |  |
|---|---|---|
|  | Bamboo | 2 |
|  | Wood | 3 |
| The thickness of tin | Above 0.35 mm | 2 |
|  | Less than 0.35 mm | 5 |
| Window | Size above 4′*4′ | 2 |
|  | Less than 4′*4′ | 5 |
| Door | Size above 3.6′*6.6′ | 1 |
|  | Less than 3.6′*6.6′ | 4 |

162   *Analysis has been based on criteria collected from "Construction Manual on Shelters for Cyclone-
163   Prone Coastal Areas of Bangladesh" proposed by Disaster Management Bureau (DMB) of the
164   Ministry of and Disaster Management and Relief (MODMR) and the Bangladesh University of
165   Engineering & Technology (BUET).

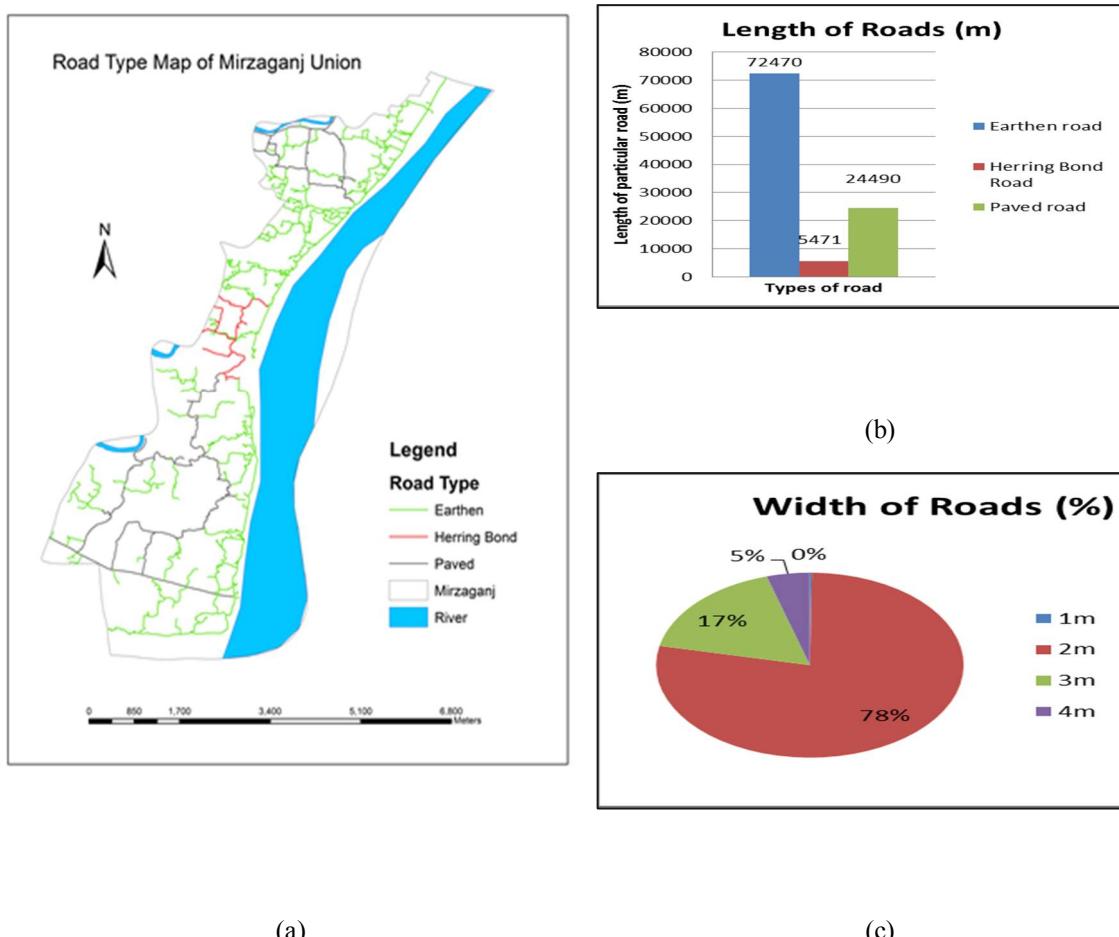
166      Figure 4(a) shows the vulnerability map of the studied union. Figure 4(b) indicates that among
167   3220 surveyed infrastructures 24 are with very low vulnerability (1%), 145 are with low vulnerability
168   (4%), 1114 are with moderate vulnerability (35%), 1887 are with high vulnerability (59%) and 50 are
169   with very high vulnerability (1%). It also shows that about 5% households are with low to very low
170   vulnerable to cyclone and 95% households are not strong enough to withstand cyclone.

(a)                                                    (b)

171   **Figure 4:** (a) Map of vulnerability of infrastructures; (b) Infrastructures with various vulnerability
172                                              ranges.

173    *3.2 Existing Road Network System*

174    Network Analysis in GIS is based on graph theory and topology. It is often used to find solutions
175    to transportation problems by using either vector or raster models to represent the real world. The
176    vector-based model appears to be more suited to analysis of precisely defined paths such as roads
177    and rivers [44]. For a proper evacuation, a good road infrastructure is needed. Road network in
178    coastal villages are still in rudimentary stage and path to the cyclone shelters remain unsafe prior to
179    the landfall of cyclone because of excessive rainfall, high wind velocity, flooded terrain and tidal
180    waves. Most of the time, roads are damaged by storm surge and make an obstacle for community
181    people from going to safer places.

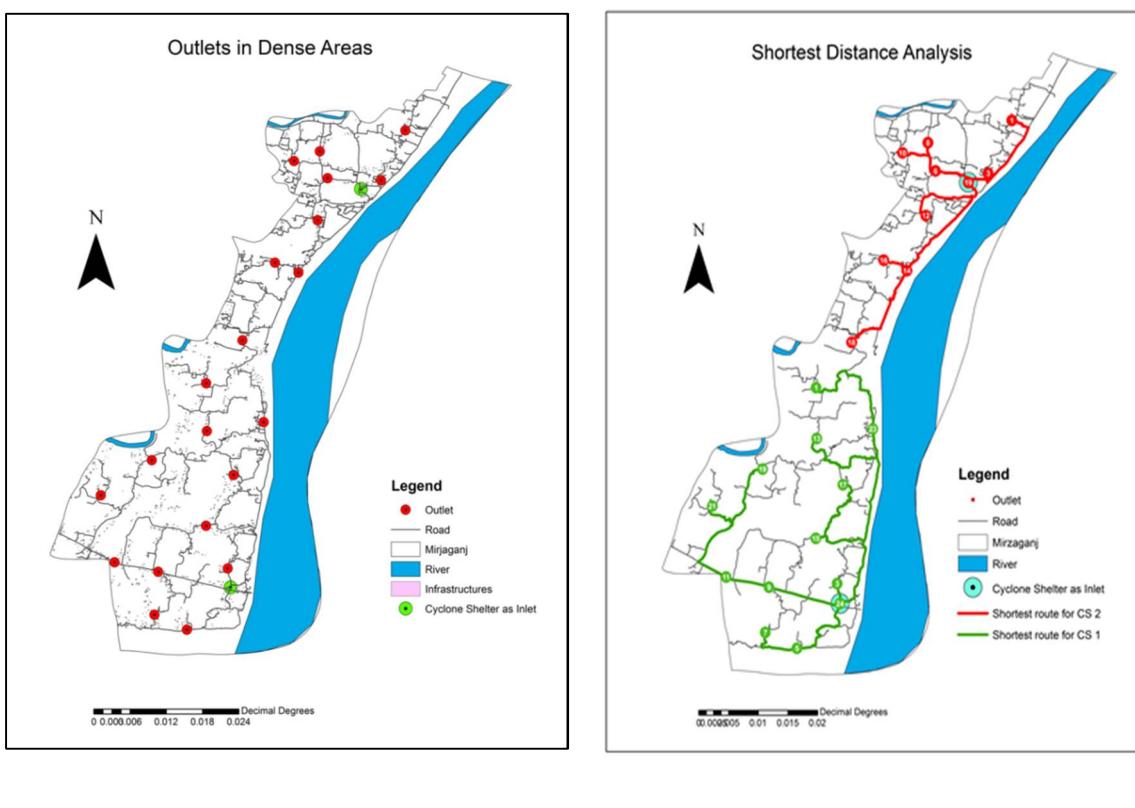
182    Figure 5(a) presents the map of road types of Mirzaganj Union. In this map three types of roads
183    (earthen road, herring bond road, and paved road) have been shown. In Figure 5, three types of roads
184    and lengths of the particular roads are presented. Among those 72.47 kilometers are earthen road
185    (71%), 24.49 kilometers are paved roads (24%) and 5.4 kilometers are herring bond roads (5%). It can
186    be clearly seen that half of the total road is of earthen type and is the most vulnerable during a cyclone.
187    For this reason during a cyclone earthen road may be a snag for community people for evacuation.
188    Besides width of roads play an important role during evacuation. Wider roads allow more people to
189    evacuate than congested roads.

(a)                                                    (c)

190    **Figure 5:** (a) Road types of the Union; (b) Length of Roads in meters; (c) Width of Roads in
191                                    percentages.

192    *3.3 Evacuation Route Analysis*

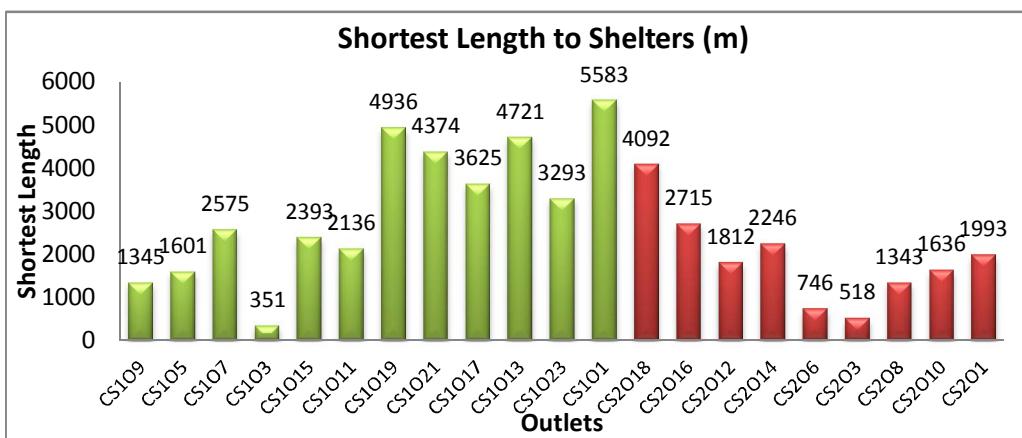
193    It has been already mentioned that there is no delineated evacuation plan in this union. While
194    warning system of Bangladesh is improving day by day but evacuation remains as a challenge
195    because of lack of government plan. If there is a shortest route earmarked for every dense area, people
196    will be able to reach to the cyclone shelters properly. Before analyzing the shortest distance we have
197    considered cyclone shelters as inlet where people will take refuge and in every dense area we
198    assumed a point as outlet from where maximum people can gather and evacuate to the shelters. In
199    this study, based on the accessibility to shelters and distance from the main roads, 21 evacuation
200    points (outlets) are marked around the study area. These outlets are situated at or near to the
201    significant roads.

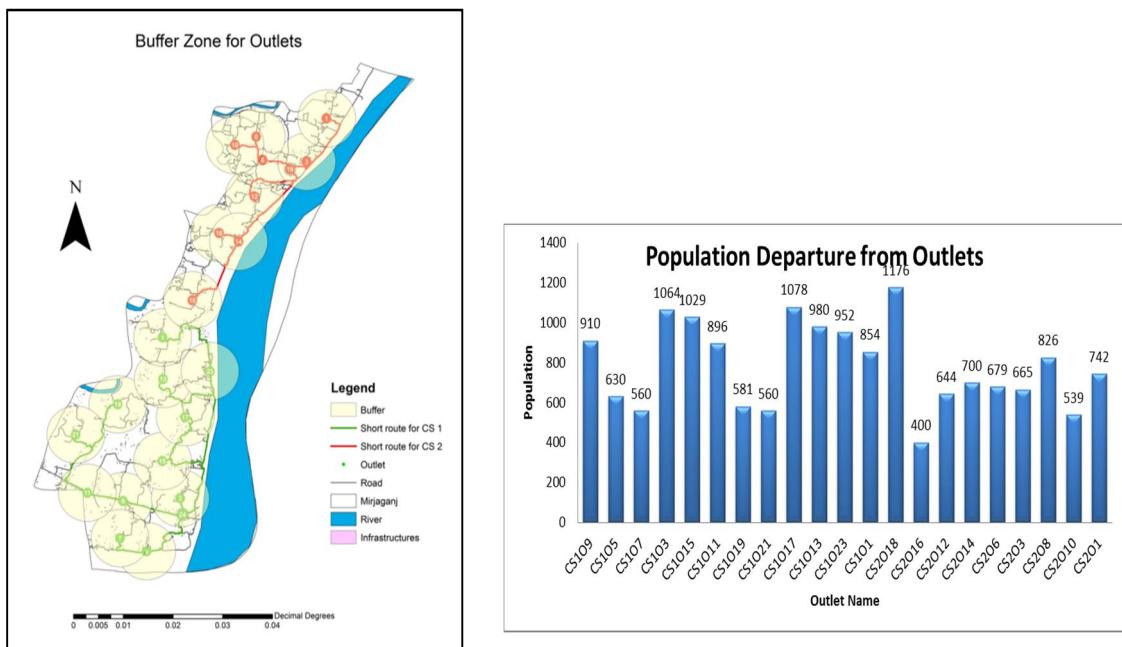
202    Figure 6(a) shows the outlets in the densely populated areas from where maximum people can
203    be evacuated to the shelters and 6(b) shows the shortest distance from every outlet to the nearest
204    shelter. From every outlet to inlet shortest distance has been analyzed using Network Analysis Tool
205    in ArcGIS 10. As there are two inlets, the total outlets are divided into two areas as can be seen in
206    Figure 6. Green colored routes are presented as the shortest distances to cyclone shelter no 1 and red
207    colored routes are presented as the shortest distances to cyclone shelter no 2.

(a)                                                             (b)

208    **Figure 6:** Outlets and Inlets in Mirzganj Union (a), Shortest Distance Analysis of Mirzaganj Union
209                                                            (b)

210

211          Figure 7 presents the shortest distances from the different outlets to the shelters. The
212    shortest distances for shelter no 1 are colored with green and the shortest distances for shelter 2 are
213    colored with red. For shelter no 1, the shortest distance is 351 meters from outlet which is marked as
214    CS1O3 (which means, CS1 is Cyclone shelter 1 and O3 is outlet 3) and for shelters no 2, the shortest
215    distance is 518 meters from outlet which is marked as CS2O3.

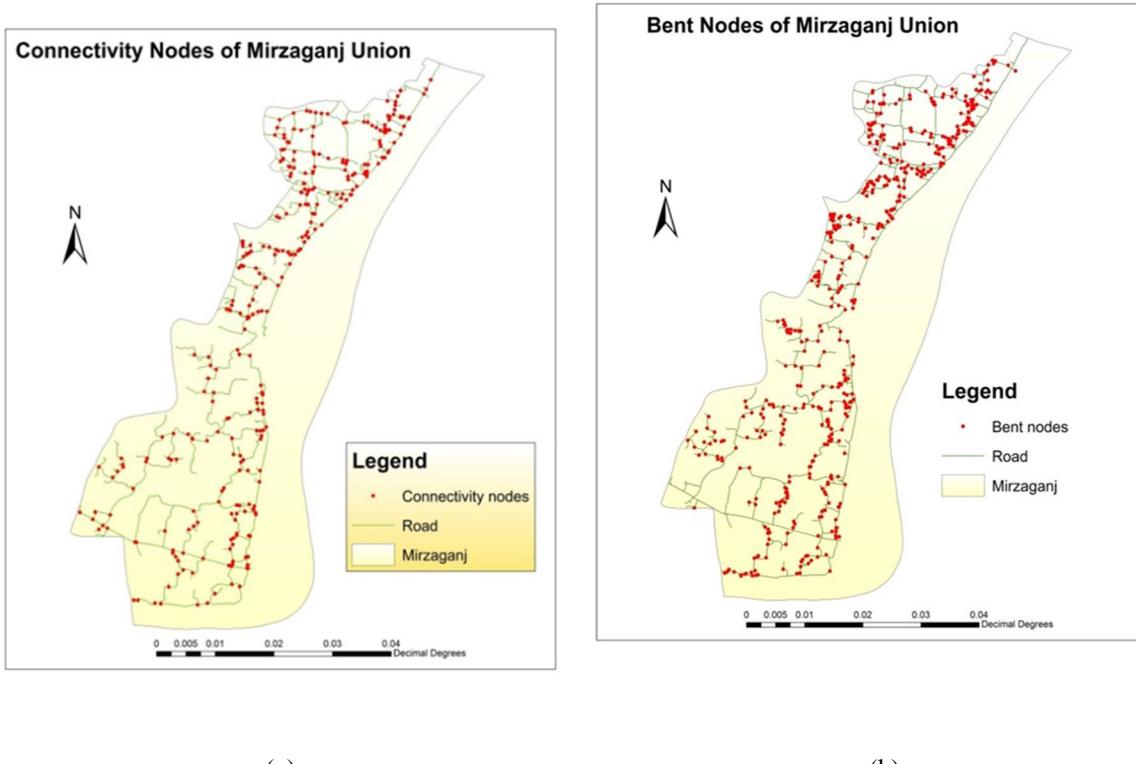
216          In Figure 8 buffer zones have been developed keeping the outlets as the centers with 600
217    m radius to assume how many people are covered for evacuation. It shows that 16465 people (based
218    on field survey) can be evacuated to shelters, which is70% of total population. Time is also an
219    important factor for real time evacuation. The shortest distance along with the shortest time can be
220    the best solution for assuming how much time it will take to move to the shelters through the shortest
221    distance from each outlet. However, from the field survey we have found that during cyclone
222    different types of factors like connectivity nodes and bent nodes may affect the travel time.

223

224                              **Figure 7:** Shortest length to Shelters

(a)                                                      (b)

225          **Figure8**: Buffer Zones for Outlets (a), People departing from each Outlet in Bar Chart (b).

226         Figure 9shows the various bent nodes and connectivity nodes of the road network that
227   cause delays. The placement of bent nodes and connectivity nodes are put in those places from where
228   people would take turn to other roads and where roads have crossed each other.

229         In Table 3, we have developed a map of bent node network in which we have assumed 2
230   seconds delay for the bent nodes and in the map of connectivity node network we have assumed 4
231   seconds delay for the connectivity node for every shortest length to shelter. In Table 3, walking
232   distance has been assumed 3.6 kilometers per hour or 60 meters per minute.

(a)                                                        (b)

233                    **Figure 9:** Connectivity Nodes Map (a) and Bent Nodes Map (b)

234   **Table 3:** Shortest Time Analysis considering factors

| SL No. | Outlet name | Shortest length (m) | Walking speed= 60 m/min* | Shortest time without bents (min) | Time consuming for bent node (s) | Time consuming for connectivity node (s) | Total time consumed due to the bents (min) | Final shortest time (min) |
|---|---|---|---|---|---|---|---|---|
| 01 | CS1O9 | 1345 | 60 | 22.40 | 15*2= 30 | 9*4= 36 | 1.1 | 24 |
| 02 | CS1O5 | 1601 | 60 | 26.70 | 14*2= 28 | 5*4= 20 | 0.80 | 28 |
| 03 | CS1O7 | 2575 | 60 | 42.91 | 13*2= 26 | 5*4= 20 | 0.77 | 44 |

| 04 | CS1O3 | 351 | 60 | 5.85 | 21*2= 42 | 14*4= 56 | 1.63 | 8 |
| 05 | CS1O15 | 2393 | 60 | 39.88 | 25*2=50 | 8*4= 32 | 1.37 | 41 |
| 06 | CS1O11 | 2136 | 60 | 35.60 | 1*2= 2 | 6*4= 24 | 0.43 | 36 |
| 07 | CS1O19 | 4936 | 60 | 82.26 | 17*2= 34 | 10*4= 40 | 1.23 | 84 |
| 08 | CS1O21 | 4374 | 60 | 72.90 | 18*2= 36 | 17*4= 68 | 1.73 | 75 |
| 09 | CS1O17 | 3625 | 60 | 60.41 | 18*2= 36 | 8*4= 32 | 1.13 | 62 |
| 10 | CS1O13 | 4721 | 60 | 78.70 | 16*2= 32 | 14*4= 56 | 1.47 | 80 |
| 11 | CS1O23 | 3293 | 60 | 54.88 | 18*2= 36 | 14*4= 56 | 1.53 | 56 |
| 12 | CS1O1 | 5583 | 60 | 93.05 | 19*2= 38 | 9*4= 36 | 1.23 | 94 |
| 13 | CS2O18 | 4092 | 60 | 68.20 | 26*2= 52 | 15*4= 60 | 1.87 | 70 |
| 14 | CS2O16 | 2715 | 60 | 45.25 | 28*2= 56 | 15*4= 60 | 1.93 | 47 |
| 15 | CS2O12 | 1812 | 60 | 30.20 | 25*2= 50 | 13*4= 52 | 1.7 | 32 |
| 16 | CS2O14 | 2246 | 60 | 37.40 | 19*2= 38 | 19*4= 76 | 1.9 | 39 |
| 17 | CS2O6 | 746 | 60 | 12.40 | 18*2= 36 | 7*4= 28 | 1.1 | 14 |
| 18 | CS2O3 | 518 | 60 | 8.60 | 38*2= 76 | 17*4= 68 | 2.4 | 11 |
| 19 | CS2O8 | 1343 | 60 | 22.38 | 22*2= 44 | 20*4= 80 | 2.1 | 25 |
| 20 | CS2O10 | 1636 | 60 | 27.30 | 17*2= 34 | 12*4= 36 | 1.17 | 29 |
| 21 | CS2O1 | 1993 | 60 | 33.20 | 34*2= 68 | 25*4= 100 | 2.8 | 36 |

235    *Walking speed 3.6 km/h or 60 m/min [45].

236    Figure 10 shows time to reach to the shelters from the outlets using the shortest routes
237    considering bents along the path for the two shelters.

(a)                                                           (b)

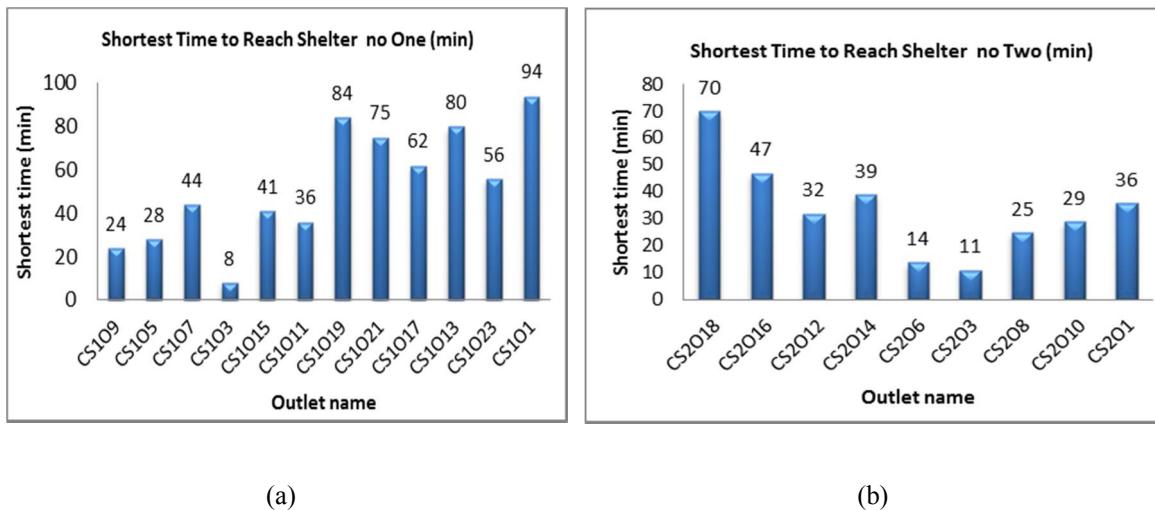



**Figure10:** Shortest Time (minutes) from each Outlet

It has already been mentioned that 1300 people can take shelter in each cyclone shelter. In reality about 4000 people take shelter in each of them and there is always overcrowding as reported by LGED (2014). Maximum 8000 people can use two shelters. On the basis of these data, two scenarios (with 1300 capacity and with 4000 capacity) have been developed to show how many people can be safe from cyclone by taking asylum in the shelters separately.

Figure 11 shows population departure from different outlets for the shelters (having 1300 capacity). In this figure, Green color represents the outlets from where people will be able to take refuge to the shelters since the time for evacuation from these outlets are the shortest. On the other hand, Red color represents the outlets from where people will be unable to take refuge to the shelters since the time for evacuation from these outlets are relatively high that means the shelters will be fully occupied before the people from these outlets reach the shelters.

Figure 11(a) shows the number of people departing from each outlet that cover the capacity (1300 people) of the cyclone shelter number one. It is observed that 1064 people can depart from outlet CS1O3 and only 236 people can depart from outlet CS1O9 to fully occupy shelter one. Similarly for Figure11(b), it is observed that 665 people can depart from outlet CS2O3 and only 635 people can depart from outlet CS2O6 to fully occupy shelter number two.

(a)　　　　　　　　　　　　　　　　　　　　　　　(b)

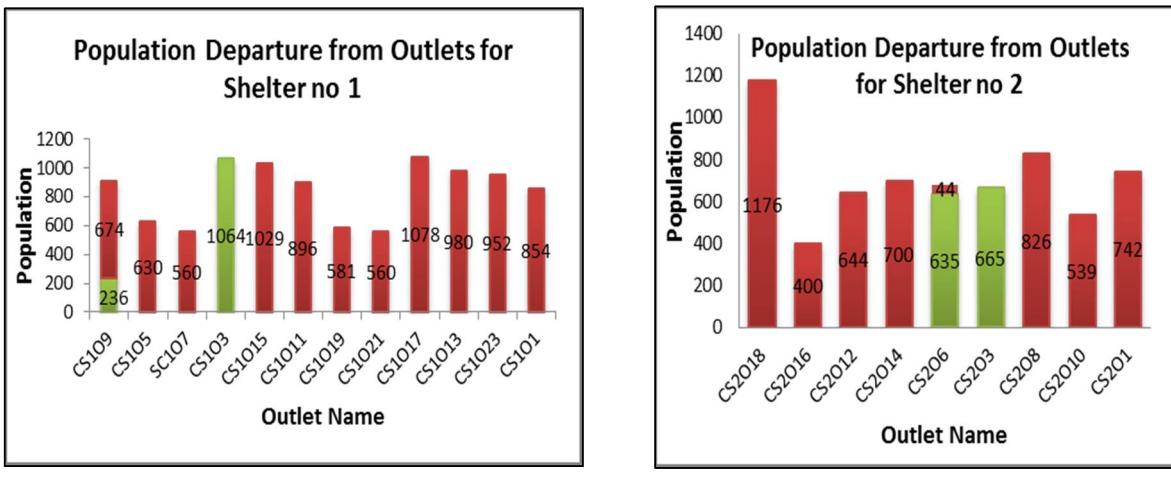



**Figure11:** Population from outlets that cover (a) Cyclone Shelter number 1; (b) Cyclone Shelter number 2;when capacity is 1300 people in per shelter.

Figure 12 shows population departure from different outlets for the shelters (having 4000 capacity). Figure 12(a) shows the number of people departing from each outlet that cover the capacity (4000 people) of the cyclone shelter number one. It is observed that 3500 people can depart from outlet CS1O5, CS1O3, CS1O15, CS1O11 and only 500 people can depart from outlet CS1O9 to fully occupy shelter one. Similarly for Figure 12(b), it is observed that 3451 people can depart from outlet CS2O1,CS2O3, CS2O6, CS2O8, CS2O10 and 549 people from CS2O12 to fully occupy shelter number two.

(a)　　　　　　　　　　　　　　　　　　　　　　　(b)

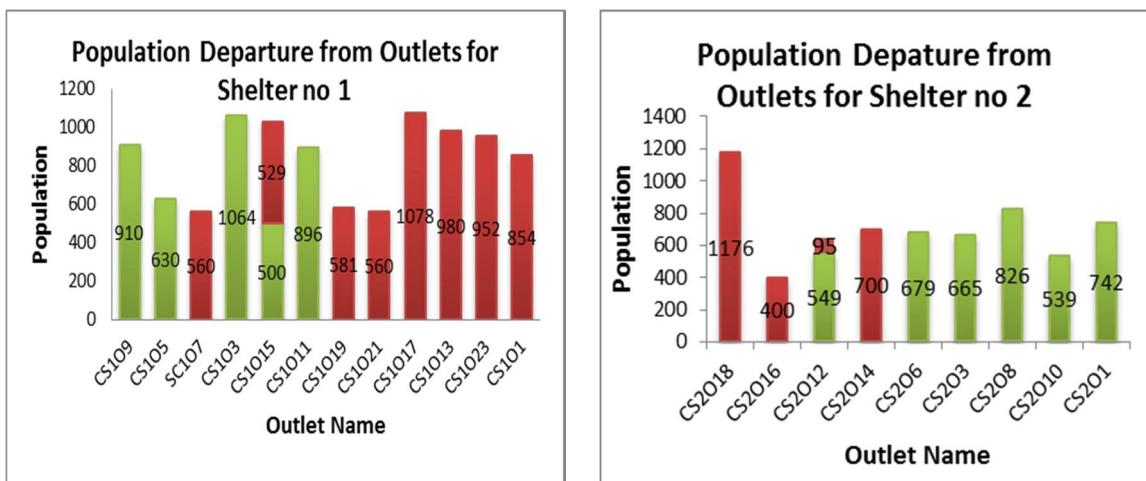



**Figure12:** Population from outlets that cover (a) Cyclone Shelter number 1; (b) Cyclone Shelter number 2; when capacity is 4000people in per shelter.

Figure 13 show that having capacity of 1300 people in each cyclone shelters can cover only 12% of the total population of the union. On the other hand, if the capacity is 4000 persons per shelter, it may cover 36% of the total population union. From Figure 4, it has been seen that about 5% (169

269  infrastructures) of total infrastructures are of low and very low vulnerability that can also be used as

270  shelter during cyclones. These infrastructures include primary schools, mosque, homesteads (high

271  plinth level with sturdy construction, as can be seen in Figure 3a). It has been assumed that average

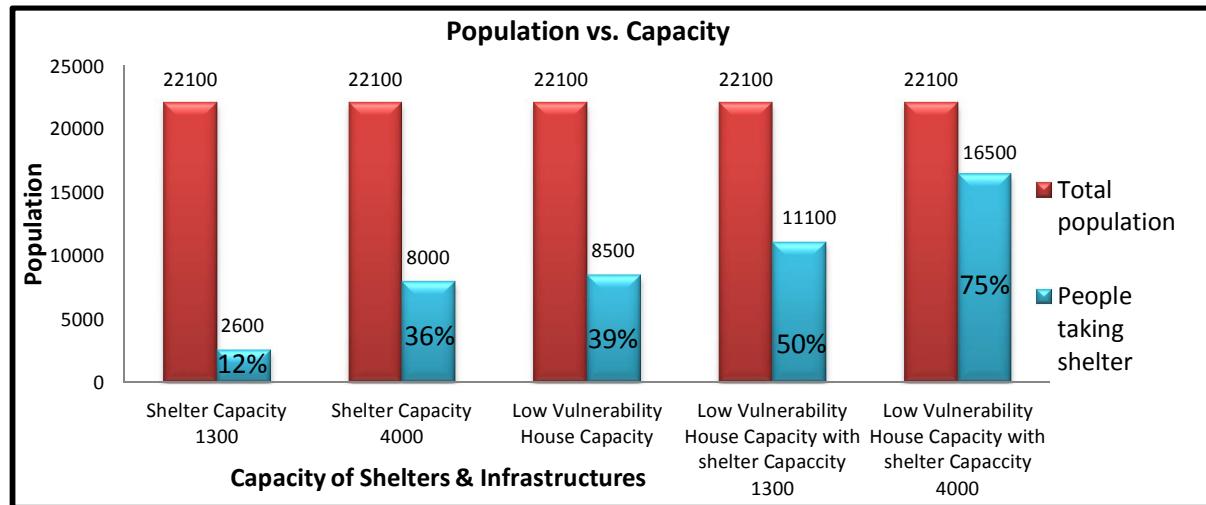
272  50 persons can take shelter in these low vulnerable infrastructures covering 39% of the total

273  population. If the capacity of the cyclone shelter has been considered as 1300 then with low

274  vulnerable infrastructures, the capacity can be increased up to50% of the total population. And if we

275  consider maximum capacity of the shelters to be 4000, along with low vulnerable infrastructures the

276  capacity can be increased up to 75% the total population.

277

279  **Figure13:** Population demand versus capacity under various scenarios

280  **4. Conclusions**

281  For a developing country like Bangladesh, the death rate due to cyclone is reducing day by

282  day. The 2007 Cyclone SIDR is not less devastating than the cyclone of 1991but the death toll has been

283  reduced due to proper early warning dissemination. It is a clear indication that we are improving

284  ourselves in disaster management sector. Hence, death rate could be reduced more if the evacuation

285  has been conducted in a scientific manner. For a proper evacuation, departure route need to be

286  developed and followed. Interview with people affected by cyclones has showed that the number of

287  cyclone shelters in the study area is inadequate. The household condition is also vulnerable. The

288  different existing road types have been considered for the development of evacuation route. More

289  outlets have been suggested in the dense areas from where more people may go to the shelters.

290  Analyzing the shortest distance and time from every outlet to shelters, it has been found that if we

291  consider the shelter capacity to be 1300, only 12% of the total population can be accommodated into

292  the shelters. If we consider, the shelter capacity to be 4000, only 36% of the total population can be

293  accommodated into the shelters. If we consider the low vulnerable infrastructures, 75% of the total

294  population can be accommodated. This study provides us an idea how we can manage our

295  population to find out suitable nearby shelters. This study can be used as a role model for coastal

296  belts of Bangladesh for developing a detailed cyclone evacuation plan for the coastal community.

297

298    **References**

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